Name of the Student:_____
Max. Marks : 21 Marks **Time : 21 Minutes**

Mark Schemes

Q1.

(a) Either
- Equation (for speed of light) only contains (universal) constants

OR
- Speed of light is invariant / constant / same in all reference frames / does not depend of speed of source or observer. ✔

Both bullet points above and **one** from
- Constants don't depend on reference frame or speed of source / observer

OR
- (refers to the) speed of light as being in free space / vacuum ✔

Speed of light is constant in equation is not enough for MP1.

Do NOT allow speed of light is invariant in all inertial reference frames for MP2 but condone for MP1.

Ignore calculations of speed of light

2

(b) Use by manipulation or substitution of

$$l = l_0\sqrt{1-\frac{v^2}{c^2}}$$ ✔

to give 69 m ✔

Condone substitution and working leading to 21 m e.g. $38\sqrt{1-\frac{2.5^2}{3^2}}$ = *21 for 1 mark only. (mixes up* l_0 *and l)*

$$l_0 = \frac{l}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{38}{\sqrt{1-\frac{2.5^2(\times 10^8)^2}{3.0^2(\times 10^8)^2}}}$$

Allow use of $v = \frac{s}{t}$ *and* $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$ *for either route.*

93 m comes from $\frac{38}{\sqrt{1-\frac{2.5}{3.0}}}$ *and gains 1 mark.*

2

(c) Evidence of idea that kinetic energy = total energy - rest energy ✔

$$E_k = \frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_0c^2$$

with substitutions correct ✔

1.21 or 1.22 × 10^{-10} (J) ✔

If no other mark awarded, give one mark for calculation of total energy (2.72 × 10^{-10}J) or rest energy (1.5 × 10^{-10} J)

Use of $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ *with* $E_k = \frac{1}{2} mv^2$ *is 0 marks*

In MP2 allow use of γ from earlier (b) but value must be seen here.

Allow rest energy = 938.3 × 10^6 × 1.60 × 10^{-19} as part of calculation.

At least 3 sf

Allow 1.23 × 10^{-10} (J)

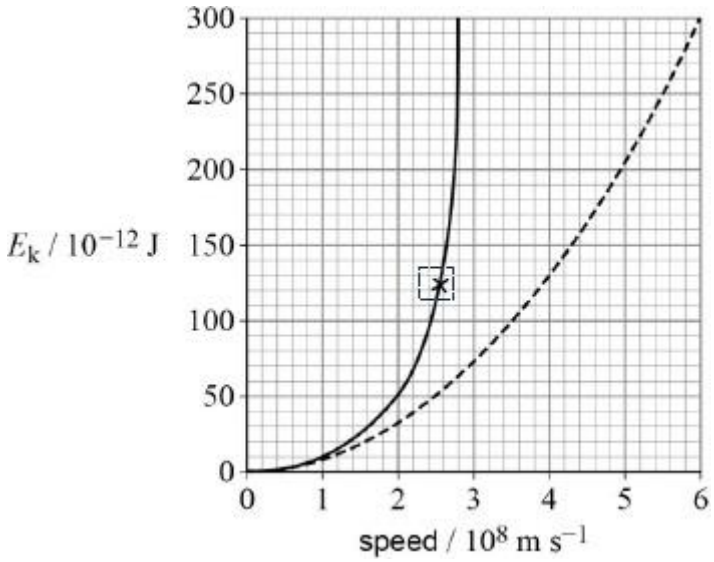
A substitution missing the squares and showing 2.2 × 10^{-10} J is eligible for MP2.

3

(d) Follows dashed line up to v = 1; condone divergence starting anywhere from v = 0.3 to v = 1.1 ✔

Increasing gradient passing within one grid square of (2.5, 122) ✔

Increasing gradient and does not go beyond v = 3 ✔



For MP3, if line reaches v = 3 must be asymptoti'c

MP3 should not be awarded if continuing the line would clearly cross v = 3

3

[10]

Q2.

(a) Light consists of corpuscles that travel in straight lines ✔

Condone 'particles' for 'corpuscles'

Accept description of travelling in straight lines.

(which means that) shadows are formed with sharp edges ✔

In MP2 accept: no diffraction, ***only/just*** *2 lines/fringes seen, sharp shadows, lines are distinct*

Treat references to interference as neutral.

(b) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.**

Mark	Criteria
6	All three areas covered well. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to cover all 3 areas, but one area may only be covered partially.
4	Two areas successfully covered, or one covered and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area covered and one covered partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	One area covered, or two covered partially
1	Only one area partially covered.
0	No relevant analysis.

Accept information seen in an appropriate diagram.
The following statements are likely to be present.

A alterations to experiment
Slits separation / width should be closer to wavelength of wave.
Make slits narrower and closer together.
Use monochromatic (red) light.
Use a single slit (to make the light coherent).
Use a laser as it is coherent/ monochromatic.

B description of Huygens' theory
Light is a wave.
The theory uses the idea of (secondary) wavelets.
Every point on wavefront acts as source of secondary wavelets.

C explanation in terms of Huygens
(When wave reaches slit) each point at slit produces secondary wavelets.
Wavelets overlap on screen.
Path difference due to different distances between a point on the screen and the two slits.
Path difference introduces phase differences.
Bright fringes form where path difference is whole number of wavelengths/waves arrive in phase.
Dark fringes where path difference is odd number of half wavelengths/waves arrive in antiphase. Do not accept 'out of phase'.

The mention of destructive/constructive interference or diffraction on its own does not gain credit.

6

(c) (Most of the screen dark)

Newton's theory predicts:

(bright) central spot surrounded by partial shadow ✔

Credit labelled additions to diagram

Condone MP1 for any suggestion of gradual decrease in brightness moving out from central region, e.g. suggestion it resembles a central maximum with no other maxima. Do not accept fringe.

Huygens' theory predicts:

(bright region with) fringes around the edge ✔

edge of bright region / fringes coloured ✔

3

[11]